NOTE ON A GLACIALLY-STRIATED PAVEMENT IN THE KUTTUNG SERIES OF THE MAITLAND DISTRICT.

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(Plate xxii., and one Text-figure.).

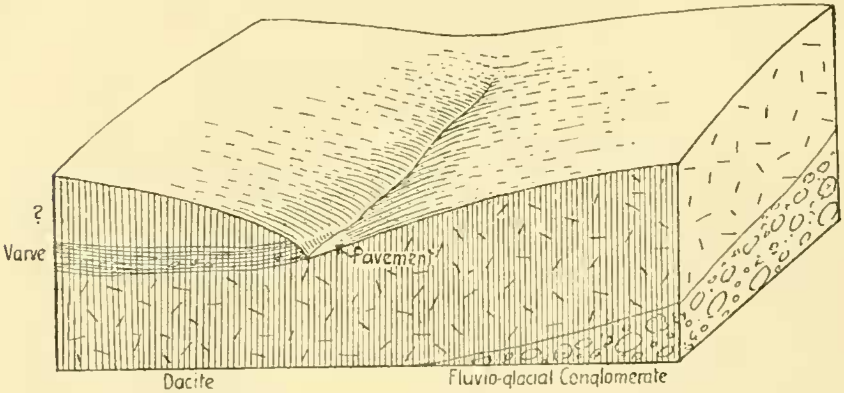
Our knowledge of glaciation of definitely Carboniferous age in New South Wales dates back to the visit of the British Association for the Advancement of Science to this State in 1914, when, during one of the geological excursions, Professor David made the discovery of definite tillite at Seaham, in the Maitland District, an identification which was concurred in by Professors Penck and Coleman. Following on this discovery, field work, chiefly by Mr. C. A. Sussmilch and also by Professor David and others, resulted in the identification of further evidences of Carboniferous glaciation in the shape of tillites, fluvio-glacial conglomerates containing faceted and striated pebbles and seasonally-banded glacial shales—varve rock—on various horizons, sometimes exhibiting contemporaneous contortion. The results of these researches are embodied in an important paper by Mr. Sussmilch and Professor David (Journ. Proc. Roy. Soc. N.S. Wales, liii., 1919, pp. 246—338).

Glacial conglomerates and varves have now been recognised in many localities in the Southern Carboniferous areas as well as further north at Currabubula, near Tamworth (These Proceedings, xlv., 1920, p. 286), but apart from the occurrence of the Seaham tillite and the indication by the existence of varves of the proximity of land ice to the site of their deposition, no definite evidence of the presence of such land ice at any particular spot in the Hunter Valley had been obtained until the recent discovery of the striated pavement which forms the subject of this note.

One of the authors (W.R.B.) is at present engaged in the investigation of the Carboniferous rocks occurring principally in the parishes of Wolfingham and Gosforth, near West Maitland, and it was during a short visit by both authors to these districts in February last, that the pavement was found, the actual discovery being due to Osborne.

The pavement is situated in portion 10, Parish of Wolfingham, near the eastern boundary of the parish. A surveyed road, leading from the neighbourhood of Gosforth to Paterson Township, after ascending a spur of the scarp bounding the plateau, forms the boundaries between portions 10 and 13. At the north-east corner of portion 13 this road is crossed by a creek, a tributary of Webber's Creek, and in this creek, about 100 yards east of the road, a very good section of varve rock is seen, the varves showing a dip of 18° in direction N. 35° W. These rocks are underlain by a dark, fairly massive mudstone possessing a sub-conchoidal fracture and containing indeterminate plant remains, and the outcrop is continued up a small tributary gully or creek coming in from the south and running approximately parallel to the road and about 200 yards to the east of it. Proceeding up this creek about 250 yards one comes upon the pavement, of which there are two exposures in the bed of the creek, separated from one another by a distance of about 2 chains.

As is frequently the case in the Carboniferous areas, the creek has eroded the junction between the dipping varves and the underlying harder rocks, and it is in this way that the pavement, which has quite probably been obscured by alluvium until comparatively recently, has been exposed. (*See* Text-figure).



Block diagram, illustrating the physiographical and stratigraphical position of the striated pavement

The total area of the pavement observable is small, probably not above six square feet at each exposure, but if the overlying varve rock and soil were removed a much greater glaciated surface would doubtless be brought to light. The rock has been smoothed, grooved or fluted, and striated, and small indentations have been produced by the "scooping-out" action of the ice. In addition, a little ledge of the rock composing the pavement, which evidently rose about a couple of inches above the general level, has also been glaciated, and now shows sub-horizontal grooving along its vertical face.

There can be no reasonable doubt that this striated pavement represents the action of ice. The possibilities of differential erosion along flow lines in the igneous rock of the pavement, and of slickensiding have been considered and rejected, and, besides, the markings are similar to those observed at Bacchus Marsh (Vic.), Inman Valley and Hallet's Cove (S.A.) and elsewhere, but the grooves are less deeply incised owing doubtless to the ice-sheet which produced them being thinner than that which glaciated the above three areas so heavily.

The direction of the striae on the glaciated surface is N.13°W—S.13°E. The sense of the movement of the ice has been determined by the examination of a depression, scooped out on the original floor and subsequently filled with varve material, the profile of which indicates that the ice was moving in a northerly direction. This indication of the ice having had an origin to the southward is of great interest. For, from palaeogeographic considerations and from the evidence of the various conglomerate horizons in the Kuttung Series, especially the Wallarobba Conglomerates occurring as a marginal belt to the present New England massif, it seems reasonable to infer that a considerable area of high land existed to the north-east of the present Carboniferous areas (*cf.* Sussmilch and David, 1919, pp. 277—281) right on till the advent of glacial conditions in Upper Kuttung time. On the other hand, the occurrence in the fluvio-glacial conglomerates of Winder's Hill and in the Lochinvar shales of pebbles of gneiss and amphibolite such as have been found by one of the authors on certain parts of the Monaro, seems to suggest that some of the material might have come from the south and south-west. It will be interesting to see whether further discoveries confirm the general south to north direction for the movement of the glaciers.

The floor over which the ice has moved is composed of a biotite dacite, the same which has formed Webber's Creek Falls and which also forms part of the steep eastern escarpment of Lamb's Valley. At the upper exposure it is overlain by well-laminated varve-rock, dipping here N.5°W. at 16½°. In the lower exposure the varve just near the contact contains numerous angular and sub-angular inclusions of various sizes up to about 9 inches in length, many of which are composed of the underlying dacite.

The existence of this striated pavement in direct contact with the varves puts it beyond a doubt, if any existed, that the latter are of glacial origin and entirely comparable with those described by De Geer and Sayles.

As regards the actual horizon of the dacite which bears the glacial markings, it is impossible to say with certainty in what part of the sequence it comes. The section from Winder's Hill to Lochinvar given in the paper by Professor David and Mr. Sussmilch shows fairly accurately part of the sequence in the Gosforth district. On this section two varve horizons are indicated. A third or middle horizon of varves should have been shown at the foot of the first dip-slope south of Winder's Hill, its stratigraphical position being somewhere between the glacial conglomerates and the green tuffs which form the horizon marked (8) on the section mentioned.

Now as one climbs the scarp of what we may for convenience call the Webber's Creek Plateau from the south-east by Bell's track, one crosses first the equivalents of the Winder's Hill conglomerate (the lowest varve is obscured by talus) then, ascending stratigraphically, a rather narrow band of varve, well seen just at the top of the ridge near Mr. Bell's homestead, is encountered, on top of which, or separated from it by only a thin band of conglomerate, is the dacite which further to the east exhibits the glacial striae, this being immediately overlain, as already stated, by a further band of varve-rock. We have not yet examined the sequence any higher than this, so that it is impossible to tell whether the dacite separates the Upper and Middle Varves, being in that case the stratigraphical equivalent of the green tuffs of the Winder's Hill section. But this seems the most reasonable interpretation in the present state of our knowledge. This would put the horizon of the pavement just about that of the varve-rock near the Seaham Hotel, or just a little below that of the Seaham Tillite.

One of the authors (G.D.O.) who has studied the Carboniferous rocks in the Paterson area is of opinion that the Webber's Creek dacite bears a close lithological resemblance to the so-called Paterson "rhyolite." It is only by further field work that any correlation can be established or disproved.

The authors are very much indebted to Professor Sir Edgeworth David for having made a trip to the site of the pavement, the result of his personal observations completely confirming their conclusions as to the glacial origin of the phenomena.

EXPLANATION OF PLATE XXII.

Figs. 1 and 2.—Photographs of the upper exposure of ice-scratched pavement. The little ledge a few inches high to the right of the hammer has also been striated. The direction of the ice-movement has been from right to left of the picture.

Fig. 3.—Photograph of a rubbing of the upper exposure of the pavement. The arrow indicating the direction of the ice-movement has been placed over the position of the depression from which the direction was determined